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Applicant :S.J. HILL et al.

Appl No. : Not Yet Assigned PCT Branch

I.A. Filed : December 24, 1999 PCT/AU99/01164

For :FLUID MIXING DEVICE

CLAIM OF PRIORITY

Commissioner of Patents and Trademarks

Washington, D.C. 20231

Sir:

Applicant hereby claims the right of priority granted pursuant to 35 U.S.C. 119 based upon Australian Application No.PP7936, filed December 24, 1998. The International Bureau already should have sent a certified copy of the Australian application to the United States designated office. If the certified copy has not arrived, please contact the undersigned.

Respectfully submitted,
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I, KAY WARD, TEAM LEADER EXAMINATION SUPPORT AND SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PP 7936 for a patent by LUMINIS PTY LTD filed on 24 December 1998.

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Seventeenth day of February 2000

K Ward

KAY WARD
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LUMINIS PTY. LTD.

AUSTRALIA

Patents Act 1990

PROVISIONAL SPECIFICATION

for the invention entitled:

"Device to Provide Fluid Mixing Which is Sensitive to Direction and Speed of External Flows"

The invention is described in the following statement:

- 24/12/98

DEVICE TO PROVIDE FLUID MIXING WHICH IS INSENSITIVE TO DIRECTION AND SPEED OF EXTERNAL FLOWS

This invention relates to fluid mixing devices and in particular to such devices which mix one fluid with another fluid that may be flowing with widely variable direction and speed. In the following description the invention will primarily be described with reference to burner applications in which a combustible fluid (or fuel) is mixed with air to produce a flammable mixture. The invention is however not limited to this application and can be used in a wide variety of fluid mixing devices particularly where one of the fluids is flowing and a second fluid is required to be mixed with the flowing fluid in a relatively stable manner.

Numerous applications exist in which a burner is required to provide a stable flame while being subjected to winds or draughts of widely variable direction and speed, and under highly turbulent, or gusting conditions.
Examples include flares, camping stoves, ceremonial torches and pilot burners in boilers and other industrial applications.

Flame stability is commonly achieved by the generation of a flow recirculation or a vortex flow pattern, either in the wake of a bluff-body or within the "vortex breakdown" associated with strongly swirling flows. While such flame holders are very successful in the relatively well defined conditions that occur within industrial combustion systems, the shape and size of a recirculation flow pattern generally depends upon the direction of the flow, (typically the combustion air in a burner, or the cross-wind in a flare) so that stability is provided only within a limited range of flow directions. To overcome the problem of sensitivity to the direction of the wind or cross-draught, the aerodynamic flame holder must produce a recirculating flow pattern which is

(1) independent of the direction of the wind or cross draught, and

(2) insensitive to sudden changes in speed or to wind gusts.

A limiting factor in flame stability is the propagation speed of the flame front. Flame speed

is a function of the fuel type, the air:fuel ratio and the turbulence. For most hydrocarbon fuels, the flame speed in a laminar flow (i.e. laminar flame speed) is typically less than 0.5 m/s. Although it is possible to produce stable flames in turbulent flows where the mean flow speed is an order of magnitude higher than the laminar flame speed, the actual local flame speed is still limited by the laminar flame speed. In contrast, instantaneous winds speed in gusting conditions readily exceeds 20 m/s and can reach speeds of 100m/s or more. Hence a further purpose of a flame holder is to provide an aerodynamic "shield" which protects the flame (or at least for the root of the flame) from high speed wind gusts. The aerodynamic shield provides a zone in which the flow speed is limited to the range of values necessary for good flame stability.

It is an object of this invention to provide a fluid mixing device for mixing one fluid with another fluid. In preferred configurations it is an object to produce mixing characteristics which are resistant to changes in cross-flow direction and speed.

In other preferred configurations it is an object to provide a burner that will provide a stable flame while being subjected to winds or draughts of widely variable direction and speed.

In one aspect this invention provides a fluid mixing device including a chamber, a bluff body defining one end of the chamber, a first fluid inlet disposed and arranged toward an opposite end of the chamber from said bluff body and arranged to direct fluid toward said bluff body, a region substantially surrounding said bluff body including a flow divider defining at least one second fluid inlet to said chamber and at least one mixed fluid outlet from said chamber, a fluid flow from said first fluid inlet and/or from said second fluid inlet establishing a recirculating vortex within said chamber and resulting in a mixture of fluids from said first fluid inlet and said second fluid inlet(s) being directed through said mixed fluid outlets.

The flow divider defines a plurality of configurations which may usefully be chosen to divide the second fluid inlets and mixed fluid outlets. The second fluid inlets and mixed fluid outlets can be configured in any one of a number of arrangements depending upon the application

of the device. The succession of flow channels defined by the flow divider may function as alternate second fluid inlets and mixed fluid outlets. The inlets and outlets may be of similar or different dimensions, and can be separated radially or azimuthally.

In the application as a flame stabiliser the flow divider is advantageously of a crinkle shape or corrugated in cross section. It can in addition or alternatively be shaped to impart a swirl to the inflow and/or the outflow.

In one preferred form the flow divider is of corrugated triangular form so that the second fluid inlets and mixed fluid outlets are generally triangular in cross section. In this arrangement the second fluid inlets preferably have the apex of the triangular cross section closest to the bluff body and the mixed fluid outlets have the base of the triangular cross section closest to the bluff body. In preferred forms of the invention the device is generally symmetric in the direction perpendicular to the bluff body. In particular the preferred arrangement of the device is axially symmetric about an axis perpendicular to the bluff body. In this configuration the first fluid inlet is preferably substantially aligned with the axis of symmetry or multiple first fluid inlets are disposed in a generally symmetric manner around the axis of symmetry.

Generally, the first fluid inlet provides a first fluid that is to be mixed with a second fluid from the second fluid inlet or inlets. In applications where multiple first fluid inlets are provided some of these may also be used to deliver one or more additional fluids into the chamber.

In one application of the fluid mixing device it is used as a burner. In one preferred form, at least some of the combustion is advantageously induced to occur within the chamber. In that case, combustible fuel is admitted through the first fluid inlet and air is admitted via the second fluid inlets. For combustion to occur, the local air:fuel ratio must fall within "fuel lean" and "fuel rich" flammability limits. In some embodiments of the invention where most of the combustion occurs outside the chamber an internal flame within the chamber acts as

a pilot for the main flame.

The structure of the device according to this invention provides an arrangement which will shield an internal flame from high velocity external cross winds and further ensures that the flow velocity within the chamber is kept below the values required to extinguish combustion. This is achieved by the device producing a self stabilising flow pattern which is independent of the wind direction and speed. The independence from cross-wind direction requires that only one mode of flow patterns be established independent of external flow direction and speed. The geometry defined in the invention prevents the flow from "switching" between one vortex flow pattern and another as the cross-wind direction changes. "Switching" is undesirable because it results in a short time during which no flame stabilising mechanism is present, which occurs in a brief time between one flame stabilising vortex flow pattern being destroyed and another being established. Thus switching greatly increases the probability that the flame may be extinguished. In accordance with the preferred form of the present invention the flow of external air into the chamber can be controlled in order to opitimize mixing between the air and the fuel and thus maintain a stable combustion within the chamber.

In a preferred configuration the present invention provides a burner in which there is an ignition path between the external flame and the internal flame. The ignition path allows the external flame to ignite the internal flame, for example when the burner is first ignited, and also allows the internal flame to ignite the external flame, for example, when a high velocity gust of wind extinguishes the external flame but not the internal flame.

In the preferred burner configuration the device can advantageously be oriented such that the axis of symmetry is perpendicular to the plane of dominant external cross flow. Thus in a flare or flame exposed to atmospheric winds the best orientation of the axis of the symmetry is likely to be vertical.

In accordance with preferred features of the burner embodiment the following modifications

can enhance control of flow entering the chamber and control of flow within the chamber:

1. the flow divider may be disposed to protrude outside the chamber and beyond the end of the device;

2. the flow divider may be disposed to extend for some distance inside the chamber;

3. the bluff body may be shaped with a curve at its outer edge to provide less resistance to the flow through the mixed fluid outlets;

4. the chamber wall may be bell mouthed, curved, or bevelled outwardly at the second fluid inlets to provide less resistance to flow through those inlets to the chamber;

5. an external cap may be placed outside the chamber;

6. a flow separator may be incorporated with the flow divider to further control the flow of air in the second fluid inlets.

Various embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic plan and cross sectional view of a typical configuration of the fluid mixing device for use as a burner in accordance with the invention;

Figures 2(a) to 2(h) are schematic plan views showing alternative configurations of the flow divider to that shown in Figure 1;

Figures 3(a) to 3(c) provide three alternative schematic plans and cross sectional views of the fluid mixing device highlighting alternative configurations of the flow divider which may be advantageously employed in some cases;

Figure 4 shows three cross sectional views of the fluid mixing device according to the invention providing alternative locations of the flow divider relative to the chamber cup;

Figure 5 is a schematic cross sectional view of a fluid flow device according to the invention showing possible bluff body locations;

Figure 6 shows five possible bluff body shapes for use in the fluid flow device of this invention;

Figure 7 shows various bluff body configurations for use in the fluid flow device of this invention;

Figures 8(a) to 8(d) show some of the possible variations in cross sectional shape of

the chamber forming part of the fluid mixing device of this invention;

Figures 9(a) to 9(e) is a series of plan views of fluid mixing devices according to this invention and showing some of the possible chamber shapes;

Figure 10 is a schematic cross section of a fluid mixing device according to this invention showing the location of a first fluid inlet;

Figures 11(a) and 11(b) are views similar to Figure 10 showing the incorporation of additional inlets to the fluid flow device;

Figure 12 is a schematic cross section of a fluid flow device according to this invention showing the addition of an external cap;

Figure 13 illustrates alternative cross sectional shapes for the external cap shown in Figure 12, which may be advantageously employed for specific circumstances;

Figures 14(a) and 14(b) are schematic cross sections of a fluid flow device according to this invention showing alternative means for the incorporation of additional inlets to the chamber;

Figure 15 shows a schematic plan and cross section similar to Figure 1 illustrating possible flow patterns within the fluid mixing device according to this invention.

The present device to provide fluid mixing which is insensitive to the direction and speed of external flows is described with reference to Figures 1 and 15. When used as a burner, the fluid mixing device comprises a cup 1 which forms a chamber 2 closed at one end by a bluff body 6. A first fluid inlet (hereafter referred to as a jet inlet) 3 extends from one end of the cup and is arranged to direct a fluid flow toward to the bluff body 6. An annular region surrounding the bluff body 6 includes a flow divider 7 that divides the region into second fluid inlets 4 (hereafter referred to as external air inlets) and mixed fluid outlets 5. The chamber 2 has a cross sectional area that is larger than the cross section of the inlets 4. The operation of the burner is best described with reference to Figure 15 which schematically illustrates the approximate fluid flow patterns within the burner. The flow within the burner is characterised by a strong recirculating vortex in the region between the jet inlet 3 and bluff body 6. . The vortex is generated by the jet flow from inlet 3 toward the vortex and/or the induced inflow from the external inlets 5. A weaker base vortex of opposite direction can be

generated in the lower region of the chamber around or below inlet 3. The mixed fluid flows out of the chamber via outlets 5. The air inlets 4 produce an inflow to the chamber immediately adjacent the mixed fluid outlet 5 flows so that both inlet and outlet are subjected to essentially the same aerodynamic pressure from external cross winds.

Figures 2(a) to 2(h) show a range of shapes for the flow divider 7. These can, for example, be a rounded corrugation as shown in Figure 2(a), a square corrugation as shown in Figure 2(b), a triangular corrugation as shown in Figure 2(c) or corrugated with radial partitions as shown in Figure 2(d). Alternatively a section of complex shape can be used such as shown in Figures 2(e), (g) and (h). A cylindrical flow divider with annular inlet and outlet flow channels can also be used as shown in Figure 2(f).

Figure 3 shows some modifications in accordance with which the flow divider can be tapered, as in Figure 3(a), twisted as in Figure 3(c) or otherwise varied in shape as shown in Figure 3(b).

Figure 4 shows various positions that can be used for the flow divider 7. In some applications the flow divider 7 protrudes beyond the end of the cup 1 and/or bluff body 6. In other applications the flow divider may be flush with the rim of cup 1 or even recessed below the rim of cup 1.

Figure 5 shows a number of alternatives for the bluff body 6 with respect to the cup 1 and flow divider 7. The bluff body 6 may be located according to the particular application within the flow divider 7 or within one bluff body diameter external to the flow divider 7.

Figure 6 shows a range of shapes that can be used for the bluff body 6. The bluff body shape can be flat, rounded, cupped, conical or a complex shape, or any combination of shapes.

Figure 7 shows modified configurations for the bluff body 6. As shown the bluff body 6 may contain holes or slots of various sizes and configurations.

Figure 8 shows some variations of the cross sectional shape of the chamber formed by cup 1. The chamber can have rounded corners as shown in Figure 8(b) or curved walls as shown in Figure 8(c) such that the ratio of mean throat diameter to maximum mean diameter will not be less than 0.5 or greater than 2.0. Figure 8(d) shows a chamber formed with an internal annular ring.

Figures 9(a) to 9(e) show a top view of various shapes of the chamber formed by cup 1. The chamber may be of any cross sectional shape including, but not limited to circular, elliptical, square, rectangular, triangular or any approximation thereof.

Figure 10 schematically illustrates the location of the jet inlet 3. The inlet may be positioned at any appropriate height from the base of the chamber.

Figure 11 shows the location of additional inlets 3. These may be in the sides of the cup 1 as shown in Figure 11(a) or in the base of the cup 1 as shown in Figure 11(b) or in any combination of these two locations.

Figure 12 illustrates an external cap or plate that may be located adjacent the flow outlet. Preferably the diameter "d" of the cap, the distance h from the top of the flow divider to the cap and the diameter of the cup "D" satisfy the following relationships:

$$0.1 \leq d/D \leq 2.0$$

$$0.0 \leq h/D \leq 2.0$$

Figure 13 shows a variety of shapes that may be used for the external cap. The cap may be of any suitable curved or flat shape including those shown in Figure 13.

Figure 14 shows a modification of the burner to include additional air inlets. In Figure 14(a) the additional air inlets are shown in the side of the cup whilst in Figure 14(b) they are shown in the base. Any combination of inlets in both the base and the sides is also possible.

An important feature of the invention is its insensitivity and adaptability to variations in the external flow. Several critical dimensions of the device have been identified. Some embodiments of the invention may therefore include sensors, data processors and actuator mechanisms which can change the geometry of the device so that it can better adapt to the external flow conditions, fuel type, required flame type, industrial process requirements or pollution standards, for example. Examples of parameters which may be dynamically varied in a single embodiment of the device are:

1. distance of the jet inlet (3) from the base of the cup;
2. the orifice size and shape of the jet inlet (3);
3. the location of the divider (7), as shown in Figure 4;
4. the shape, location, number and size of the external air inlets (4);
5. the shape, location, number and size of the mixed fluid outlets (5);
6. the shape, location, number and size of additional inlets;
7. the size and shape of the chamber.

The foregoing describes only some embodiments of this invention and modifications can be made without departing from the scope of the invention.

DATED this 24th day of December, 1998
LUMINIS PTY. LTD.
by its Patent Attorneys
DAVIES COLLISON CAVE

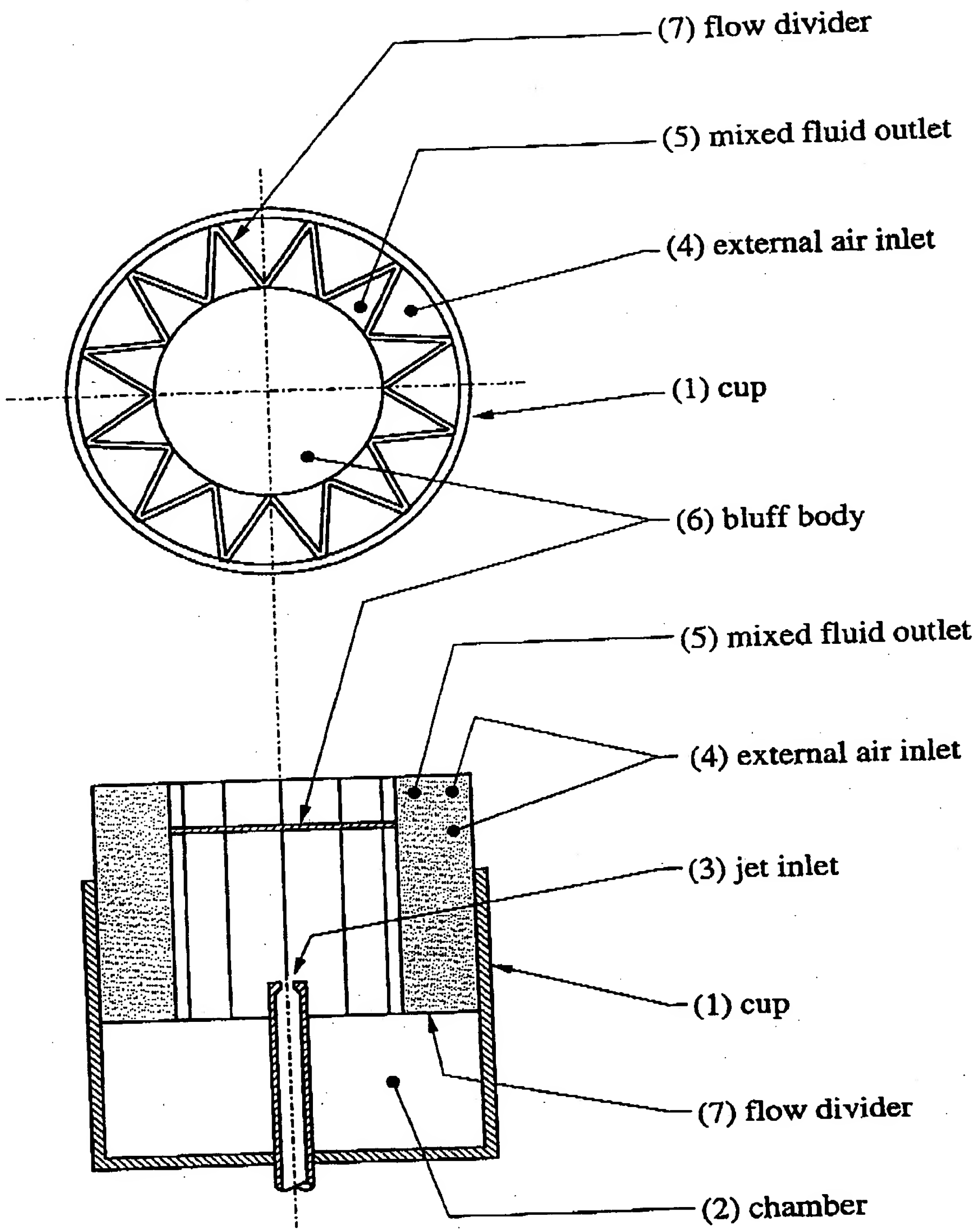


Figure 1: General arrangement

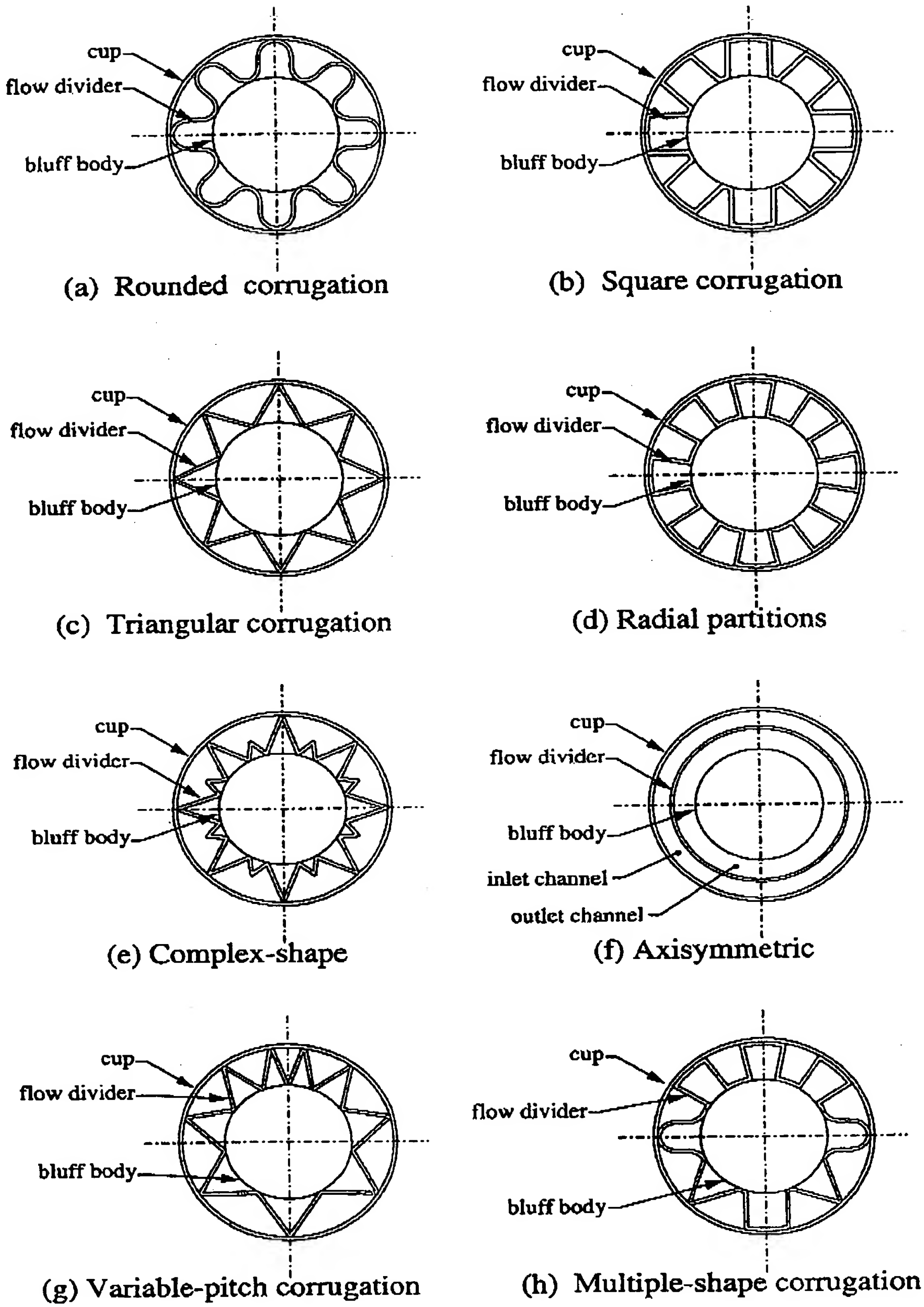
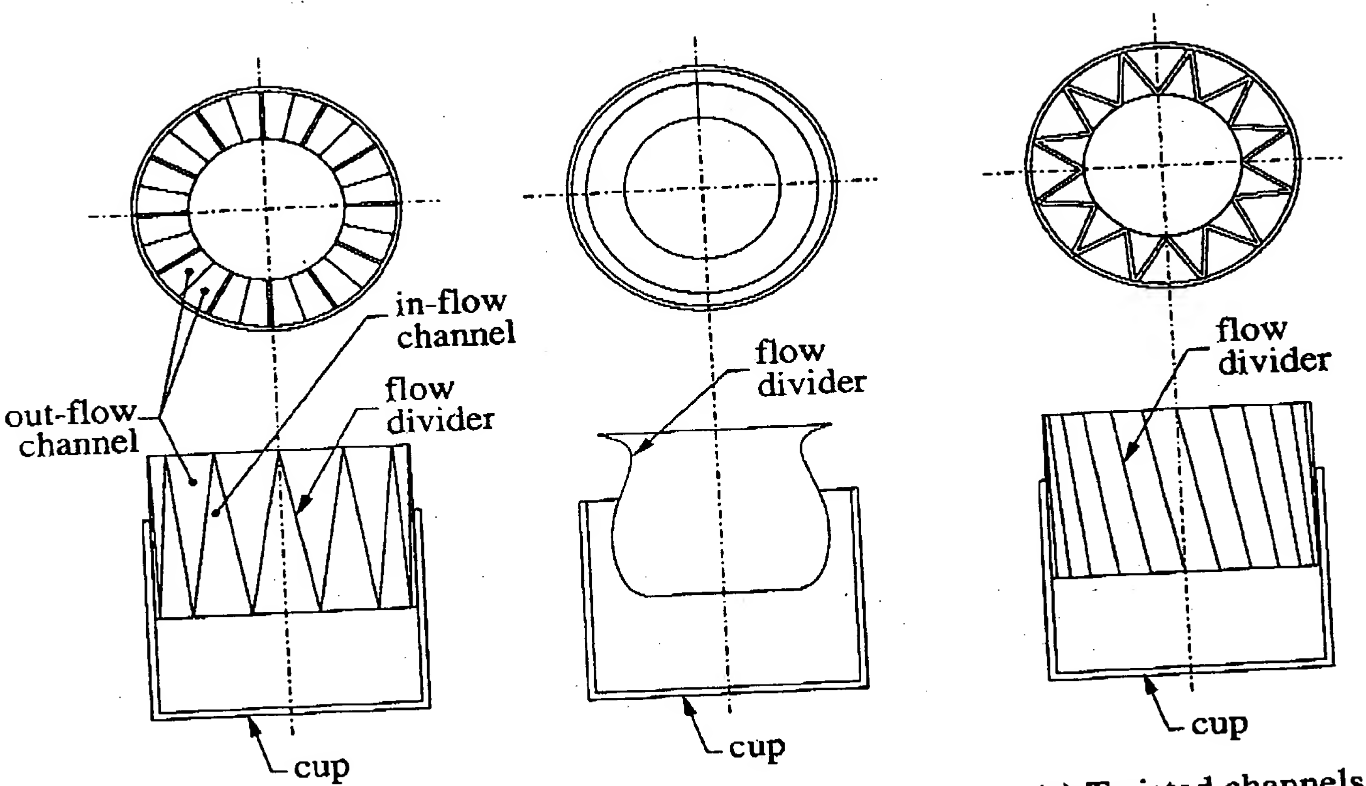


Figure 2: Cross-section shape of flow divider



(a) Tapered channels

(b) Non-crinkled contoured

(c) Twisted channels

Figure 3: Shape of flow-divider channels

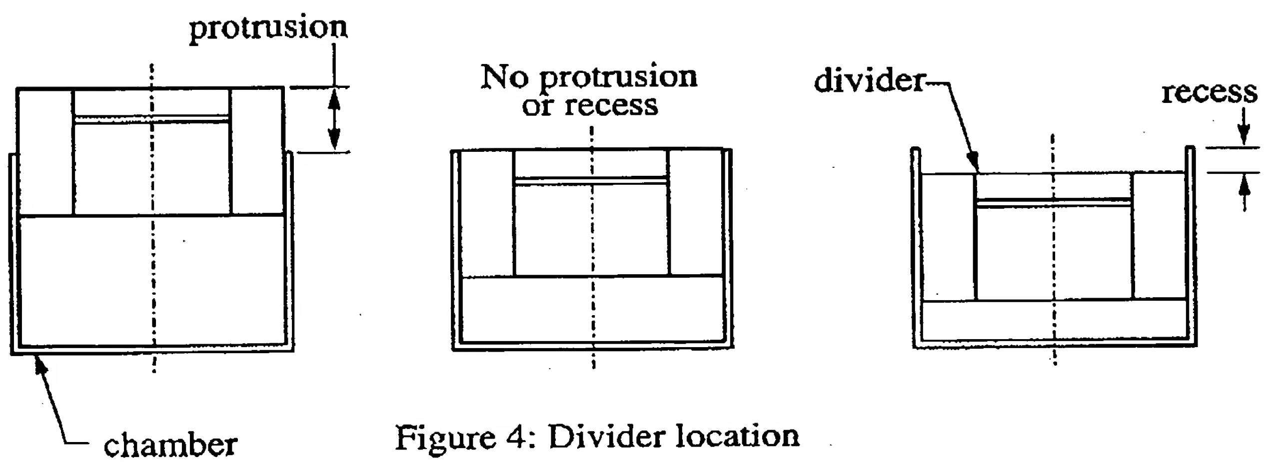


Figure 4: Divider location

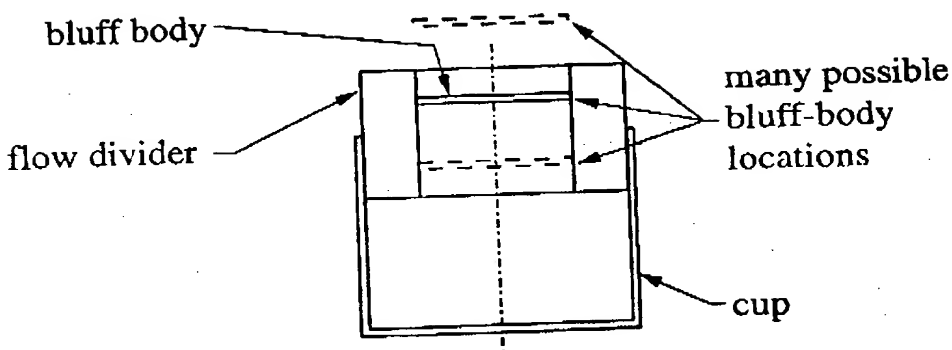


Figure 5: Bluff-body location

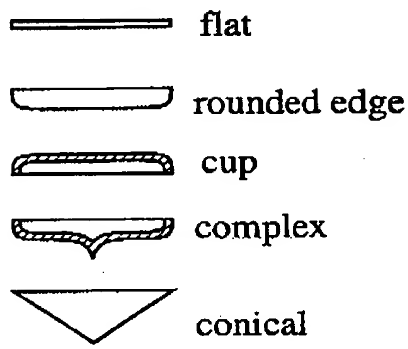


Figure 6: Bluff-body shape

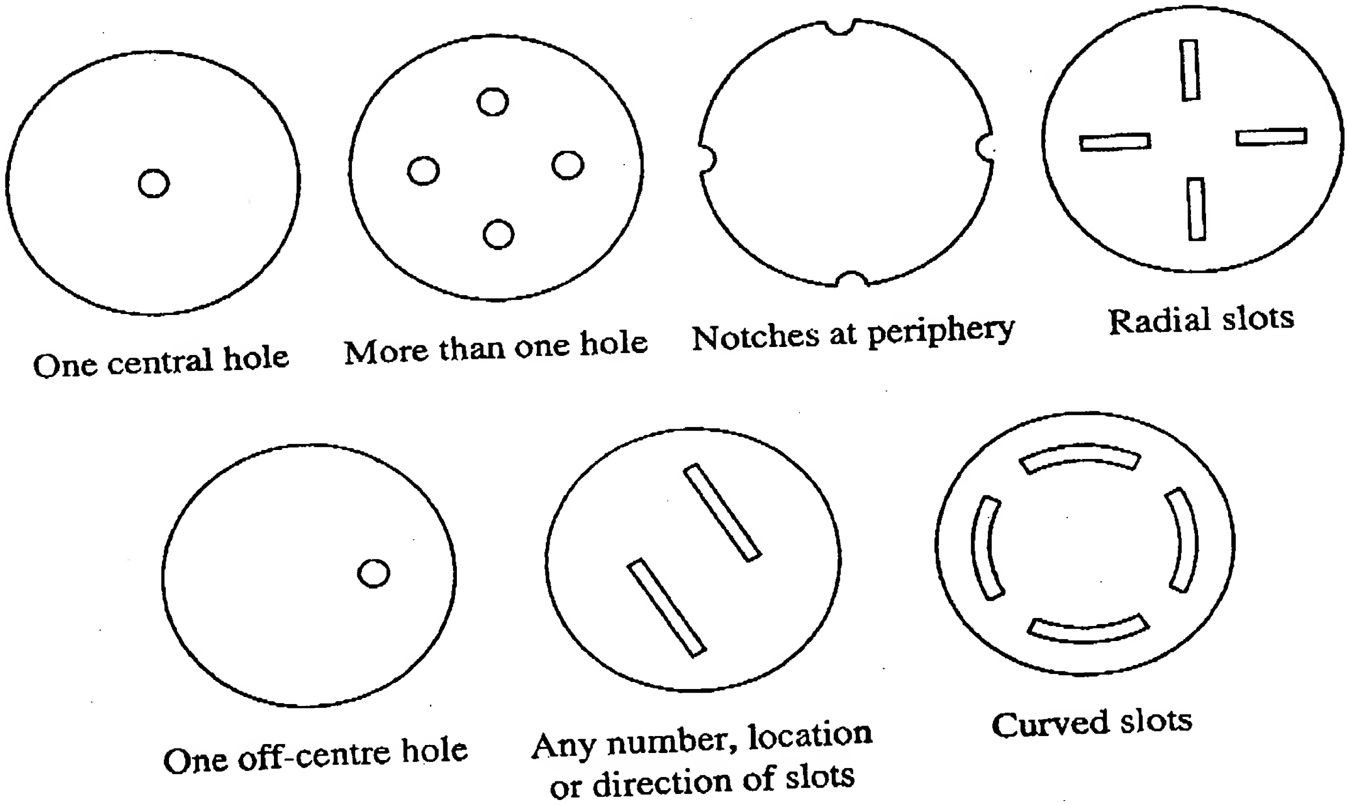
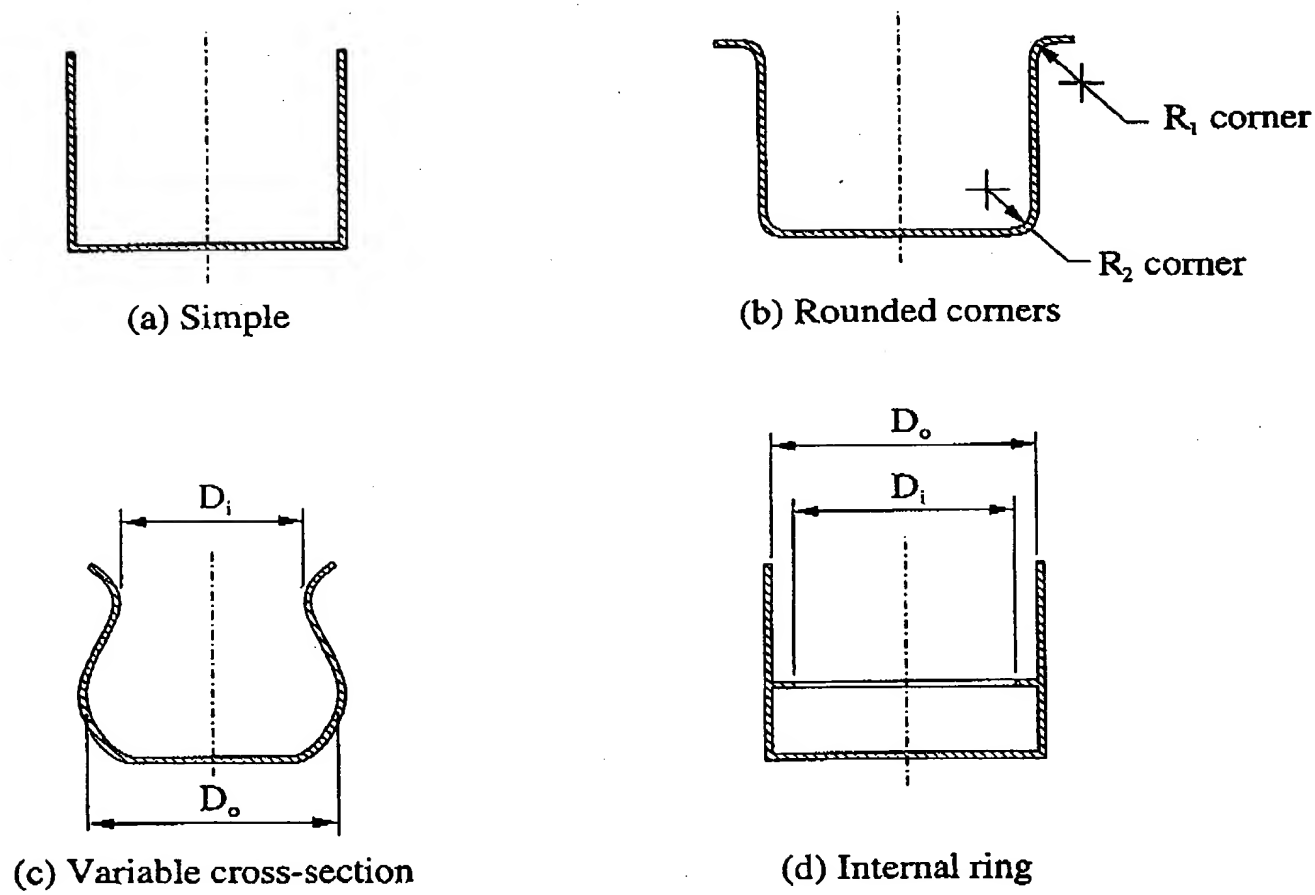


Figure 7: Holes and slots in bluff body (top view)



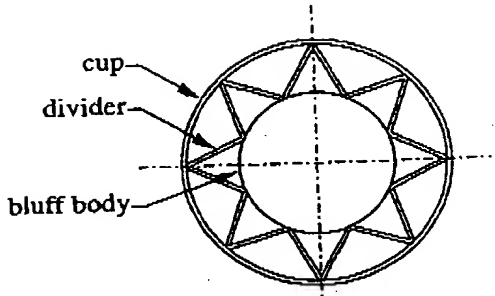
(a) Simple

(b) Rounded corners

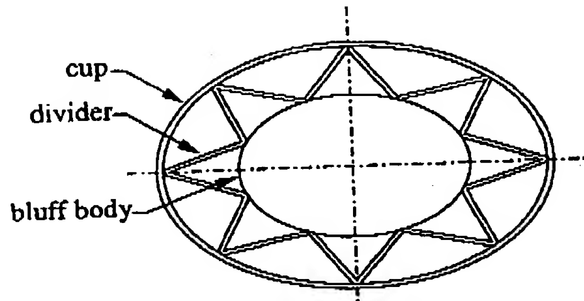
(c) Variable cross-section

(d) Internal ring

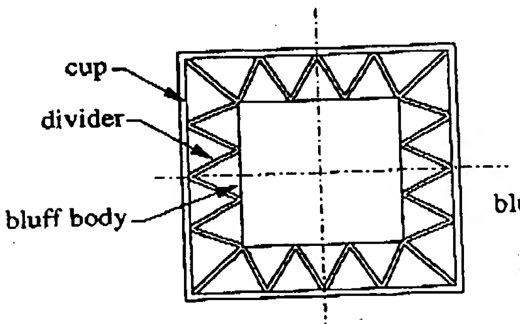
Figure 8: Cross-section shape of the chamber (side view)



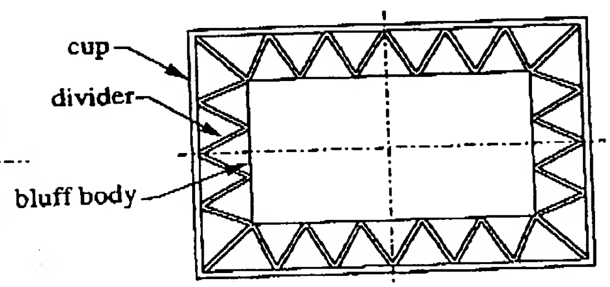
(a) Circular



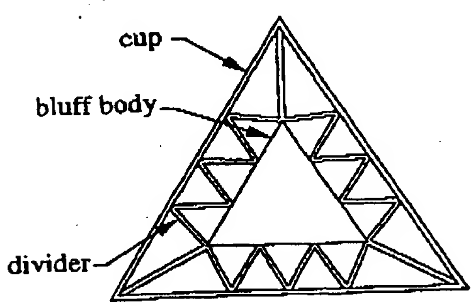
(b) Elliptical



(c): Square

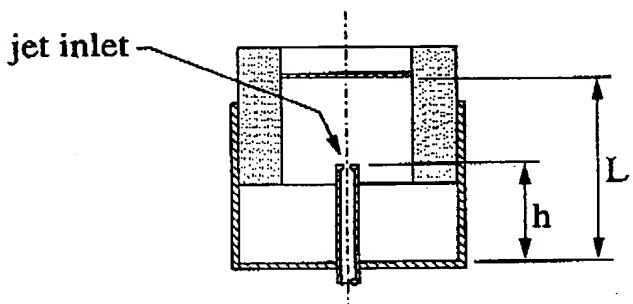


(d): Rectangular



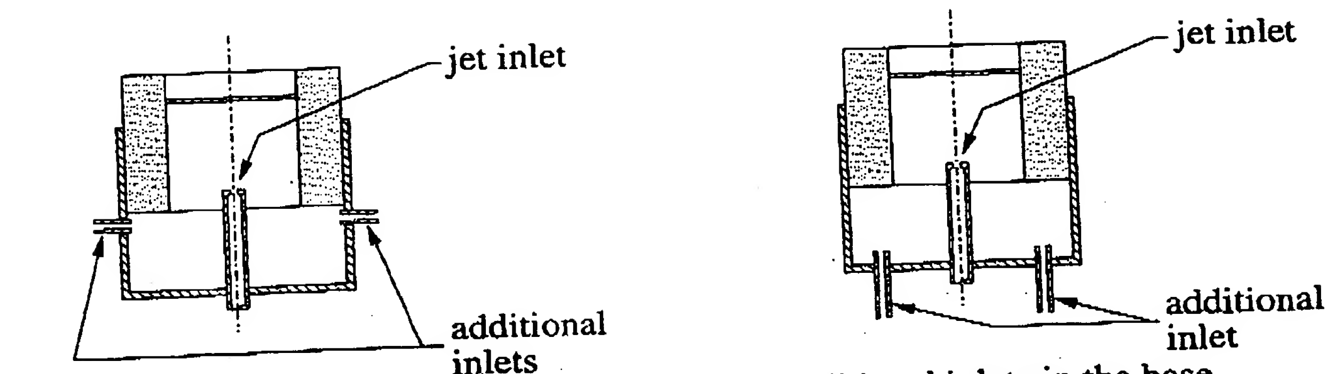
(e): Triangular

Figure 9: Shape of chamber (top view)



$0 \leq h/L \leq 1$

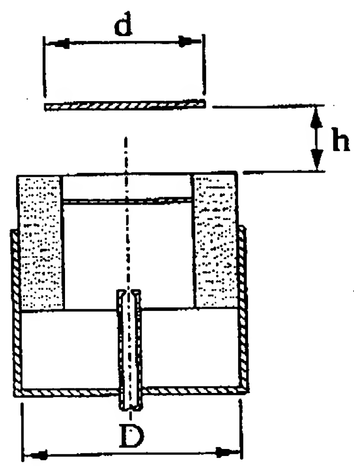
Figure 10: Location of jet inlet



(a) additional inlets in the side

(b) additional inlets in the base

Figure 11: Location of additional inlets



$0.1 \leq d/D \leq 2.0$

$0.0 \leq h/D \leq 2.0$

Figure 12: Location and size of external cap

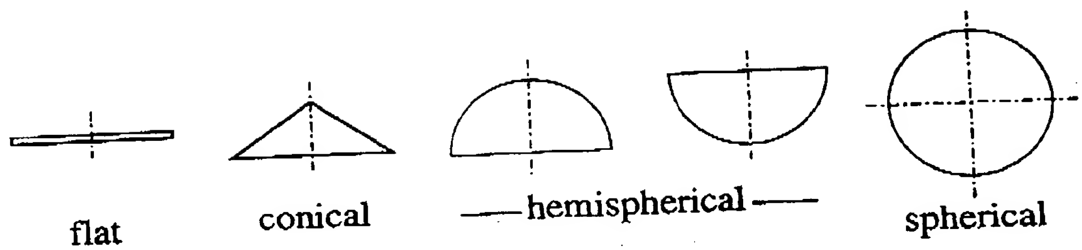
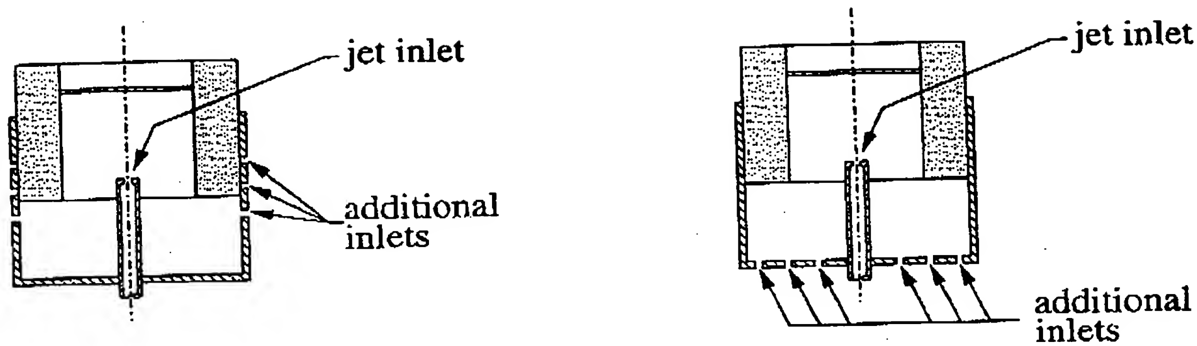


Figure 13: Shape of external cap



(a) inlets in the side

(b) inlets in the base

Figure 14: Location of additional external inlets

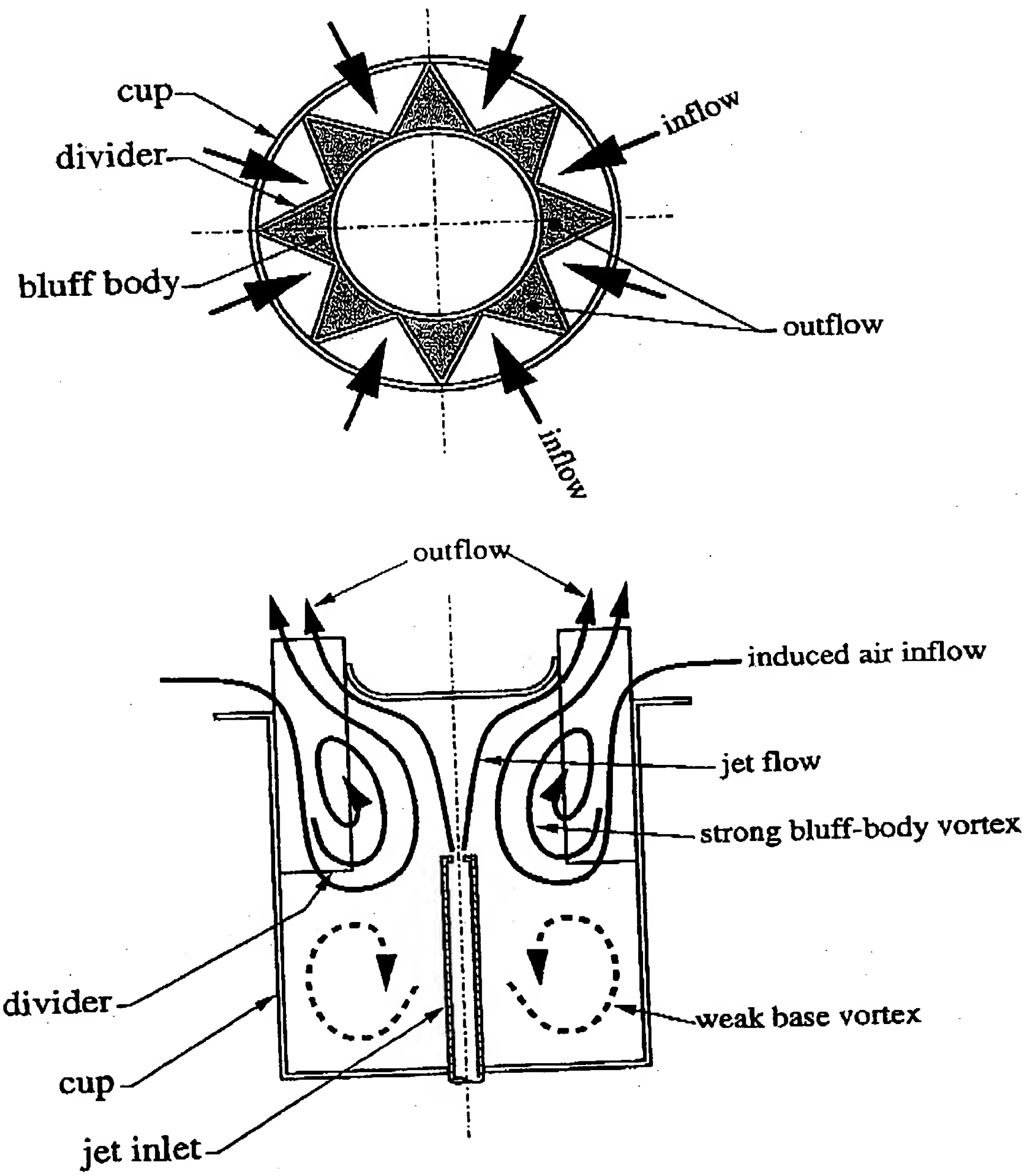


Figure 15: Flow structure in the combustor